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Combined Transmission Electron Microscopy and Atom-probe Tomography of Magnetic Tunnel Junctions

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Magnetic tunnel junctions (MTJs) are of tremendous technological interest for the next generation of hard disk drive readers and as memory elements in magnetic random access memories. The microstructural features and multilayer interfaces of this thin film heterostructure determine the magnetic and electronic properties and ultimately the performance of the MTJ. In this work, CoFeB/MgO MTJs have been investigated by a combination of transmission electron microscopy (TEM) and atom-probe tomography (APT). TEM is used to analyze the crystallography and grain structure of the multilayers, while APT is used to map the three-dimensional elemental distribution. As deposited, the CoFeB is amorphous and the MgO has a poor crystalline texture. Annealing results in partial crystallization of the CoFeB and improved MgO crystallinity, enhancing the properties of the MTJ. Here TEM is performed on the individual APT specimens allowing for a direct correlation of the crystal structure with the elemental distribution. TEM is further used to follow the tip-shape evolution of the APT specimen, yielding insights into the resulting three-dimensional reconstruction. These studies have revealed unique local compositional differences between the crystalline and amorphous grains of CoFeB that have not seen previously by any other technique, offering new insights into the resulting MTJ performance.